Science in the undergraduate curriculum during the 20th century

David J Weatherall

BACKGROUND The conflict between the art and science of medical practice has always posed problems for the presentation of the scientific basis of medicine to medical students. This issue is examined by a brief description of the changing methods of medical education over the last century.

OBSERVATIONS The various approaches to attempting to teach the scientific basis of medical practice are discussed, together with the increasing complexities that followed the explosion of knowledge in the basic biological fields towards the end of the 20th century. Although progress was made by a more integrated approach to medical education, there are still considerable problems in presenting the basic sciences to students in a way that convinces them that such material is relevant to their future practice.

CONCLUSIONS A more broadly based background in modern biology, including evolutionary biology and biological complexity, would undoubtedly better prepare students for dealing with the infinite complexities they will encounter in sick people.

KEYWORDS science/*history/education; biological sciences/*history/education; education, medical, undergraduate/*history; curriculum/*history; history, 20th century.

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Weatherall Institute of Molecular Medicine, University of Oxford, Oxford, UK

Correspondence: D J Weatherall, Weatherall Institute of Molecular Medicine, John Radcliffe Hospital, Headington, Oxford OX3 9DS, UK. Tel: 00 44 1865 222360; Fax: 00 44 1865 222424, E-mail: liz.rose@imm.ox.ac.uk

INTRODUCTION

It is a remarkable fact that, despite the extraordinary advances in the biological and medical sciences in the 20th century, the role of science compared with the art of clinical practice in the education of doctors remains almost as uncertain as it was in the 17th century. When the great English physician Thomas Sydenham returned from the Civil War to study medicine at Oxford, he was not impressed with what he saw. One of his contemporaries records that he held that it was better to send a man to Oxford to learn shoe-making than to practise medicine![1] In particular, he disliked the pretensions of doctors who seemed to believe that their scientific research was more important than their day-to-day practice, and he taught that clinical medicine could be learned only at the bedside.

Despite innumerable changes to and modifications of the medical curriculum over the last 100 years, the ghost of Sydenham still walks the corridors of our teaching hospitals and is a regular attender at the Educational Committee of the General Medical Council (GMC) and other bodies that are involved in determining how doctors should be taught. Here, I shall outline briefly the place of the basic medical sciences in the curriculum of medical students over the last 100 years and discuss how the tensions between the science and art of clinical practice are still reflected in medical education as it enters the 21st century. Some aspects of the latter topic have been discussed previously.[2,3]

THE SLOW EVOLUTION OF THE SCIENTIFIC BASIS OF MEDICAL EDUCATION

To fully appreciate the tensions between science and clinical practice in medical education in the 20th century, it is helpful to trace the way in which medical

Overview

What is already known on this subject

Despite extensive changes in the organisation of medical schools and in the curriculum for medical education in the 20th century, we still fail to impress our students with the importance of the basic biological sciences to their future work with sick people. In part, this may reflect fundamental differences in attitudes towards medical research and clinical practice.

What this study adds

This study gives a brief outline of the place of the basic medical sciences in the curriculum of medical students over the last 100 years and discusses how the tensions between the science and art of clinical practice are still reflected in medical education as it enters the 21st century.

Suggestions for further research

Paradoxically, the increasing evidence for the biological uniqueness and complexity of all of us which has followed the study of human beings in health and disease at the cellular and molecular levels offers the possibility of presenting the basic sciences to students of the future in ways that may allow the material to appear much more relevant to their work as doctors.

schools and the education of doctors evolved over this period. It will only be possible to outline some of the major changes here; an excellent account of these developments has been given by Bonner.[4]

Early beginnings

In the second half of the 19th century, first in France and later in Germany, major developments occurred in the organisation of the medical sciences. University-based laboratories were springing up in which men and women could devote their time to research and teaching in the blossoming basic sciences, notably anatomy, physiology and, later, biochemistry. In 1867, Johns Hopkins, a rich businessman in Baltimore, USA, established Johns Hopkins University, whose first president was Daniel Gilman. Gilman had spent time at the University of Berlin and was later responsible for initiating the Johns Hopkins Hospital and its medical school, designed along the lines he had observed in Europe. Departments covering the basic medical sciences were developed and well organised pre-medical and graduate training courses followed, named the Chemical/Biological Programme. Pre-medical students at Johns Hopkins were advised to complete courses in physics and chemistry before proceeding to the course in biology. Later, outstanding clinicians were recruited and slowly, and not without some acrimony, the concept of specialist clinical departments with full-time professors was established.[5]

In 1910 the American educator Abraham Flexner, who had also travelled widely in Germany, wrote a withering critique of medical education and science in North America on the basis of his visits to German universities. Apart from Johns Hopkins, he felt that the organisation of medical education in American schools was falling far behind that of schools in Germany. His report recommended that medical education begin with a strong foundation in the basic sciences, followed by the study of clinical medicine in an atmosphere of critical thinking with adequate time and facilities for research. Flexner's views on medical education in the UK were equally jaundiced, with the possible exception of Cambridge, where early developments in some of the basic biological sciences, if not clinical teaching, may have impressed him.[6]

Flexner, together with William Osler, who had recently arrived in England to become Regius Professor of Medicine in Oxford, and others, gave testimony on medical teaching before a Royal Commission in London, chaired by Lord Haldane, which reported in 1913. They made a strong case for the restructuring of medical education on a university-based pattern. Although much of the other testimony before the Commission, including that submitted by a former president of the Royal College of Surgeons, strongly opposed the Johns Hopkins model, overall the report endorsed the newer approaches to medical education in the USA and Germany. Progress was slow, however, until after World War I, at which time George Newman, the Chief Medical Officer of both the National Board of Education and the Ministry of Health, also made a strong case for university courses in medicine with effective interrelationships between studies of laboratory science and clinical practice.[4]

There were other important influences on the development of academic medicine and education

during this period. In 1886 the Association of American Physicians was founded, a body that included not only those involved in the practice of teaching internal medicine, but also representatives from a wide range of the basic sciences. A similar organisation, the Association of Physicians of Great Britain and Ireland, was established in 1907, largely due to the efforts of William Osler, although, unlike its American forebear, its membership was limited to doctors and it remained more of an intimate club that had little contact with other scientific disciplines.[7]

The concept of the full-time clinical professor took many years to be accepted. William Osler felt that it was wrong to deny clinical teachers their time in private practice and felt that they would become less able clinicians if they were, at the same time, full-time teachers and research workers, a view not held by the pioneer of biochemical genetics, Sir Archibald Garrod, when he was about to be appointed to London's first full-time professorship of medicine at St Bartholomew's Hospital in 1919. The concept remained unpopular in the UK for many years; only 8–12 professorial units with full-time staff appointed by universities existed in 1932,[8] and it was not until after World War II that the current pattern of university-based medical schools became the norm. Indeed, it was only at the Hammersmith Hospital, opened in 1935, that a completely integrated university teaching hospital along the Johns Hopkins lines was ever achieved.

This evolution of the modern medical school was undoubtedly accompanied by a variety of tensions that have still not been fully resolved. The strong antagonism on the part of the medical establishment, particularly part-time consultants at the London teaching hospitals, to the development of university teaching departments with full-time staff left in its wake the feeling that there were two types of doctors: those who were closely devoted to patient care and those whose clinical activities were peripheral to their teaching and research. Although the establishment of distinct departments in the individual basic sciences undoubtedly had a major effect in developing medical science, it tended to dissociate the scientific basis of medicine from clinical practice, not in the least in the minds of medical students.

In a thoughtful essay, Bynum addressed the thorny problem of why the historical partnerships between science and medicine, knowledge and practice, had never been straightforward.[9] He traced a tradition of medical practice, based on admiration for Sydenham's views, that is still a major force in our teaching hospitals. It reflects a view of medicine as an individualistic art founded on bedside observations and skills, with a suspicion of theory and laboratory research. But he did not see it as a naively antiscientific or dogmatic view on the part of practising doctors. In part, it may result from the different attitudes of mind required of those who produce medical knowledge and those who dispense it. Thomas Lewis summarised these qualities as follows: 'Self-confidence is by general consent one of the essentials to the practice of medicine, for it breeds confidence, faith and hope. Diffidence, by equally general consent, is an essential quality of investigation, for it breeds enquiry. Here are the chief characteristics, each necessary in its own sphere, each unsuited to the other…'[2] I have discussed this extremely important distinction previously.[2]

The pattern of medical education settles down

In the period after World War II, the pattern of medical education was more or less the same in most medical schools across the UK. There was a first MB course that covered chemistry, zoology and botany, although students who had reached high grades in these subjects at school were often exempted and went straight into the second MB course. They then spent two years during which they dissected the whole body and received instruction in physiology, biochemistry and, in some cases, psychology and related subjects. Those who managed to survive the rigours of the second MB examination then proceeded to the final MB course, which was divided into various stages, starting with pathology and bacteriology and proceeding to clinical training on the wards. The situation in some universities in the USA was slightly different, in that students had one year of the basic biological sciences and three years of clinical training, during which there was an effort to integrate physiology and biochemistry with their clinical applications.

Overall, this approach to training doctors did not provide them with a genuine understanding of the importance of the basic medical sciences for clinical practice. Because very little effort was made to relate physiology or biochemistry to disease, many students felt that their first few years in a medical school were wasted; they had come to be trained as doctors and yet their lectures and practical classes seemed to have no relevance whatever to sick people. This problem was not helped by the attitudes of some of their later clinical teachers. When the great physiologist and pharmacologist Sir Henry Dale arrived at

St Bartholomew's Hospital to study medicine in 1900, he was advised by a senior doctor, Samuel Gee, to forget all the physiology he had learnt at Cambridge as medicine was not a science but an empirical art;[7] many students in the postwar period in the UK received much the same advice (including the present author!).

There was another difficulty with this dissociation between teaching the basic sciences and clinical medicine that has not been widely discussed. Possibly because many of those who taught the pre-clinical sciences to medical students perceived their lack of interest or understanding of their relevance, they often presented their subjects in an over-simplified and didactic way. This approach often left students with the impression that the basic biological sciences comprised a well defined base of solid and completely substantiated knowledge. Hence they were often totally unprepared for the complexities and uncertainties that they encountered in sick people as they entered their clinical years. In short, they moved from a tidy, well defined world to one in which the infinite and often inexplicable manifestations of illness seemed completely at odds with what their narrow perception of the biological sciences would have predicted.

CURRICULUM REFORMS AND THE MEDICAL SCIENCES

In the latter part of the 20th century there was a major rethink about the whole process of medical education. In the USA, Case Western Reserve University initiated an organ system-based curriculum in which the old divisions between pre-clinical and clinical teaching were swept away and attempts were made to integrate the teaching of both the basic and clinical sciences throughout the students' careers. And there were other major changes in the patterns of medical education. McMaster University in Canada pioneered a system based loosely on modern educational theory where students were encouraged to teach themselves with the support of the faculty using a problem-based approach. One of the major objectives of problem-based teaching has been to present the basic sciences from a clinical viewpoint by a process of small group, self-directed learning. In the early 1980s Harvard Medical School developed a completely new curriculum based on these principles called the New Pathway Project. The dean who was responsible for this ambitious programme has written a valuable account of the stresses and strains on the staff and some of the major advantages and difficulties of this more integrated and science-based approach to medical education.[10] Similar approaches to a more integrated type of medical education were developed in the UK at the same time, particularly in some of the more recently established medical schools.

On both sides of the Atlantic there were other developments which encouraged a more focused interest in the scientific basis of medicine on the part of students. Many medical schools in the UK provided intercalated BSc courses between the pre-clinical and clinical years, a facility that had been available for many years at Oxford and Cambridge. So-called 'MD/PhD programmes' were developed in the USA. These involved a truncated period of clinical teaching combined with several years of research and research training directed towards the PhD part of the qualification. A few courses of this type were subsequently offered in British medical schools. One of the worrying features of MD/PhD programmes, particularly in the USA, was that many students trained in this way went into full-time research and the objective of producing doctor/scientists was not always achieved. Although a great deal of thought was given to establishing such courses in Oxford, it was felt that it was better for young people to complete their formal medical training, gain a few years of clinical experience, and then return with a research fellowship to work towards a PhD once they had developed some ideas about the direction of their future careers. This approach has certainly produced some outstanding clinical scientists and teachers who have remained in touch with medical practice.

Based presumably on increasing concerns about the more humane and pastoral aspects of medical care, in 1993 the GMC, under the title *Tomorrow's Doctors: Recommendations on Undergraduate Medical Education*, demanded sweeping changes in the way in which doctors are trained in the UK.[11] While incorporating some of the reforms that had been initiated in the USA, this report made demands that went much further: exposure to patients and their families from the beginning of the course; more emphasis on communication skills, ethics, social sciences, and the humanities; less emphasis on the basic medical sciences, which should be spread right across the course; and much more exposure to the pastoral aspects of medicine and medical care. Although the report appeared to leave considerable flexibility about how these changes might be achieved, the

bodies that had been established to monitor how medical schools were reorganising themselves to meet these objectives often seemed to have a limited interest in the role of the basic medical sciences and, by their rigid requirements, sometimes seemed set to stifle the diversity of the patterns of medical education in the UK.

Although admirable in many ways, the GMC's requirements, coming as they did at a time of rapid expansion in the basic medical sciences, posed increasing problems for medical schools that wished to maintain a very strong science base.

Hence, after years of continuous reorganisation of the medical curriculum, medical education moved into the new millennium in a state of uncertainty about its future direction. These problems were not made any easier, certainly in the UK, by endless governmental interference with the running of the National Health Service and uncertainties about the future standing of the medical profession in society. Current methods of medical education came under further scrutiny and questions were raised about the importance of much of the content of a medical student's curriculum. Is a broad education that includes the basic sciences really necessary? Surely a perfectly adequate, if slightly barefooted, doctor could be produced in a much shorter time and still be able to meet the needs of the community.

THE ROLE OF SCIENCE IN MEDICAL EDUCATION: CAN WE DO BETTER?

In discussions with the brightest of our students over recent years, it is apparent that many of them still have genuine doubts about the value of the basic sciences to which they have been exposed. Their argument is, as ever, that they came to medical school to become practising doctors; despite the best efforts of their teachers they complete their courses without a genuine belief that the science they have studied will have much relevance to their day-to-day clinical practice. Regardless of whether they are right, or, as I believe, wrong, their attitudes reflect the failure on the part of medical education to transmit the reasons for the central role of science in preparing for humane clinical practice.

It seems important therefore to re-examine the belief that exposure to science is important in training the doctors of the future. If it really is, and particularly in the light of the massive expansion of scientific knowledge in the biomedical field, we will have to try to define those areas that are of genuine importance, and to ask, yet again, whether we are pursuing the most effective way of combining the education of science with clinical practice.

Why do today's doctors need some background in the basic biological sciences?

The standard answer to this question is that it is not possible to understand the pathophysiology of disease without some perception of normal function. In addition, an early exposure to basic science provides students with a lifelong critical approach to medical advances and their application. While there is a good deal of truth in both these arguments, they are only part of the story.[3]

Modern developments in the study of disease at the cellular and molecular levels have emphasised the quite remarkable individuality of our genetic make-up and hence our responses to our environments. Particularly in a world dominated by medical information derived from mega-trials, the central importance of the patient as an individual is often lost; surely this is far less likely to happen if doctors really appreciate the evidence for biological individuality.

The other issue that has been highlighted by the biological sciences over the last 20 years is the multilayered complexity of all living things; sick people are no exception. Francis Crick has pointed out, unlike the case of the physical sciences, Occam's razor is an extremely blunt instrument when applied to biological systems.[12] We still understand very little about the infinite diversity and stochastic basis for many biological processes that surely must be even more complex in sick organisms. If students can be convinced of these uncertainties early in their careers, this should engender a state of humility in their approach to sick people and, *pari passu*, reduce the degree of self-certain pomposity that has characterised the medical profession over many centuries and which, incidentally, has been the basis for much of the criticism to which it has been exposed of late.

In short, a sound knowledge of scientific method, combined with an appreciation of the extreme complexity of biological systems, should provide a more rounded background for students entering any branch of medical practice and, at the same time, offer stimulation to that small handful of young people who will go on to become medical scientists and help to develop clinical practice in the future.

What kind of science and how much?

It is beyond the scope of this essay to discuss the background that students require before tackling the basic biomedical sciences. In the British system many students still come from school with the appropriate knowledge but, increasingly, the recruitment of those from diverse backgrounds into graduate entry courses will require some instruction in the basics of chemistry, physics, biology and mathematics by medical schools. This issue cannot be side-tracked; without this base it is impossible to appreciate the complexities of living things.

Although many of the basic medical sciences can be integrated into organ- or problem-based approaches to learning, the disadvantage of this approach is that it tends to present a specialist-based, compartmentalised picture that is at odds with modern developments in integrative biology. Hence, there is a good case for a short introductory programme in molecular and cell biology, evolutionary biology, information technology and the behavioural sciences. During this period, it would also be extremely valuable to provide students with some inkling of the history of the medical and biological sciences. For example, if they were to be exposed early in their careers to simple accounts of the advances in the basic sciences that led to the development of vaccines and antibiotics in the mid-20th century, and to the famous study of Comroe and Dripps,[13] which showed that at least half of the remarkable advances in cardiological care in the latter part of the century were based on curiosity-driven science that was not directed at particular clinical goals, they might start out with a much better appreciation of the value of the basic sciences for medical practice. Similarly, if at the same time, they were to gain acquaintance with the work of Ernst Mayr,[14] who defined the central questions of biological knowledge as a series of layers of increasing complexity, they would undoubtedly be better prepared for the problems they will face in the wards.

There is no reason why an introductory course of this type should not be combined with the requirements of the GMC regarding early exposure to patients, the acquisition of communication skills, and other early experiences directed at turning students into caring doctors. Nor is there any reason why some clinical examples should not be integrated into basic training in molecular and cell biology. But a short period of focus on the biological sciences, combined with some exposure to the history of the medicine and science, would give students a much better appreciation of the importance of science in the integrated courses that follow.

Ideally, the basics of anatomy, physiology, cell biology and biochemistry should be integrated in a problem- or organ-based approach. Although this is very demanding in terms of staff time and organisation, it is the only way forward if we are to try to put together the basic and clinical sciences in the future. But although this should be the central model of medical education, there are many ways in which this type of integration might be achieved; medicine is such a diverse profession that it would be a great pity if, in our attempts to improve its teaching, our medical schools were driven into a state of stultifying uniformity. And in attempting to develop a core of knowledge based on integrated teaching of this type, it is vital that the curriculum does not become so overcrowded that students lose those valuable hours spent on the wards talking to patients and their relatives; communication can only be learnt by talking to real people, not to actors in studios.

In short, as well as early exposure to patients, students need a short background course in the history of biological and medical research combined with a basic understanding of the principles of molecular and cell biology and information technology. After this, in one way or another, they should learn the principles of pathophysiology using an organ- or problem-based approach or some modification of these well tried methods. Throughout their training they must be given time to spend with their patients and families, both in hospitals and communities. This is not a call for yet another total reorganisation of the medical curriculum. Rather, it is a suggestion for some fine-tuning of the context of the student's experiences in that critical first few months after they enter medical school.

AFTERTHOUGHT

As the molecular era adds further layers of complexity to our understanding of both normal biological function and disease mechanisms, and with the development of increasingly complex information technology, we will no doubt go on meddling with the medical curriculum year by year. Some years ago I tried to summarise our problems as follows: 'The principle problem for those who educate our doctors of the future is how, on the one hand, to encourage a lifelong attitude of critical, scientific thinking to the management of illness and, on the other, to

recognise that moment when the scientific approach, because of ignorance, has reached its limit and must be replaced by sympathetic empiricism. Because of the dichotomy between the self-confidence required at the bedside and the self-critical uncertainty essential in the research laboratory, it may always be difficult to achieve this balance. Can one person ever combine the two qualities? Possibly not, but this is the goal to which medicine must aspire.'[2] Not much has changed since this was written, and there are few signs that it will in the foreseeable future.

Since my last foray into the field of how doctors are examined almost had me ejected from the Royal College of Physicians,[15] I have avoided the question of how knowledge of the scientific basis of medicine should be assessed. And as this essay was restricted to the role of science in medical education, it has not been possible to enlarge on how its teaching can be accommodated with the numerous other skills that have been introduced into the curriculum, including an over-liberal dose of the humanities, with the aim of humanising our doctors of the future. But when I see a surgeon poised over my abdomen with a knife, all that I ask is that he or she is a humble, self-critical professional whose biological and technical training has prepared their mind to cope with the infinite possibilities that lie beneath the skin, and that, when finished, they can communicate what they have done to my relatives in simple, kindly language; at that moment their skills at deciphering the arcane meanings of multiple-choice questions or their acquaintance, or lack of, with the late string quartets of Beethoven will not bother me too much.

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